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PTO/SB/05 (12/97)

Approved for use through 09/30/00. OMB 0651-0032

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 82771.P270 Total Pages 2

First Named Inventor or Application Identifier Mohan V. Kalkunte

Express Mail Label No. EM542801774US

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, D. C. 20231

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
   (Submit an original, and a duplicate for fee processing)
2. X Specification (Total Pages 34)
   (preferred arrangement set forth below)
   - Cover Sheet
   - Descriptive Title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claims
   - Abstract of the Disclosure
3. X Drawings(s) (35 USC 113) (Total Sheets 10)
4. X Oath or Declaration/Power of Attorney (Total Pages 3)
   a. X Unsigned
   b. ___ Copy from a Prior Application (37 CFR 1.63(d))
   (for Continuation/Divisional with Box 17 completed) **(Note Box 5 below)**
   i. ___ DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ___ Incorporation By Reference (useable if Box 4b is checked)
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ___ Microfiche Computer Program (Appendix)
7. ___ Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. ___ Computer Readable Copy
   b. ___ Paper Copy (identical to computer copy)
   c. ___ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. _____ Assignment Papers (cover sheet & documents(s))
9. _____ a. 37 CFR 3.73(b) Statement (where there is an assignee)
10. _____ English Translation Document (if applicable)
11. _____ a. Information Disclosure Statement (IDS)/PTO-1449
_____ b. Copies of IDS Citations
12. _____ Preliminary Amendment
13. X Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. _____ a. Small Entity Statement(s)
b. Statement filed in prior application, Status still proper and desired
15. _____ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. X Other: Certificate of Mailing (1 page in duplicate)

17. **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:
___ Continuation ____ Divisional ____ Continuation-in-part (CIP)
of prior application No: __

18. **Correspondence Address**
_____ Customer Number or Bar Code Label _____
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or
X Correspondence Address Below

NAME Allan T. Sponseller, Reg. No. 38,318
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP
ADDRESS 12400 Wilshire Boulevard
Seventh Floor
CITY Los Angeles STATE California ZIP CODE 90025-1026
Country U.S.A. TELEPHONE (503) 684-6200 FAX (503) 684-3245
Express Mail Label: EM542801774US

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FEE TRANSMITTAL

EXPRESS MAIL NO. EM542801774US

Complete if Known:
Application No. _____
Filing Date August 7, 1998
First Named Inventor Mohan V. Kalkunte
Group Art Unit _____
Examiner Name _____
Attorney Docket No. 82771.P270

METHOD OF PAYMENT (check one)

1. [ ] The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

   Deposit Account Number 02-2666
   Deposit Account Name _____
   [X] Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

   [ ] Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance, 37 CFR 1.131(b)

2. X Payment Enclosed
   X Check
   _____ Money Order
   _____ Other

FEE CALCULATION (fees effective 10/01/97)

1. FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	790	201	395	Utility application filing fee	790.00
106	330	206	165	Design application filing fee	
107	540	207	270	Plant filling fee	
108	790	208	395	Reissue filing fee	
114	150	214	75	Provisional application filing fee	
				SUBTOTAL (1)	$ 790.00

2. CLAIMS

			Extra		Fee from below		Fee Paid
Total Claims	22	– 20 =	2	X	22.00	=	44.00
Independent Claims	4	– 3 =	1	X	82.00	=	82.00
Multiple Dependent Claims				X		=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
103	22	203	11	Claims in excess of twenty	44.00
102	82	202	41	Independent claims in excess of 3	82.00
104	270	204	135	Multiple dependent claim	
109	82	209	41	Reissue independent claims over original patent	
110	22	210	11	Reissue claims in excess of 20 and over original patent	
				SUBTOTAL (2)	$ 126.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for response within first month	
116	400	216	200	Extension for response within second month	
117	950	217	475	Extension for response within third month	
118	1,510	218	755	Extension for response within fourth month	
128	2,060	228	1,030	Extension for response within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive unavoidably abandoned application	
141	1,320	241	660	Petition to revive unintentionally abandoned application	
142	1,320	242	660	Utility issue fee (or reissue)	
143	450	243	225	Design issue fee	
144	670	244	335	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	790	246	395	For filing a submission after final rejection (see 37 CFR 1.129(a))	
149	790	249	395	For each additional invention to be examined (see 37 CFR 1.129(a))	

Other fee (specify) _____

Other fee (specify) _____

SUBTOTAL (3) $ 0.00

*Reduced by Basic Filing Fee Paid

TOTAL AMOUNT OF PAYMENT ($) $ 916.00

SUBMITTED BY:

Typed or Printed Name: Allan T. Sponseller

Signature _____ Date August 7, 1998

Reg. Number 38,318 Deposit Account User ID _____ (complete if applicable)

PTO/SB/17 (10-96)
Approved for use through 09/30/98 OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Our Ref.: 82771.P270

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

Method And Apparatus for Preserving Frame Ordering Across Aggregated Links Between Source and Destination Nodes

Inventor(s): **Mohan V. Kalkunte**
James L. Mangin
Ian Crayford

Prepared by:

BLAKELY SOKOLOFF TAYLOR & ZAFMAN, LLP
12400 Wilshire Boulevard, 7th Floor
Los Angeles, California 90025
(503) 684-6200

"Express Mail" label number EM542801774US

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METHOD AND APPARATUS FOR PRESERVING FRAME ORDERING ACROSS AGGREGATED LINKS BETWEEN SOURCE AND DESTINATION NODES

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of data networking and, in particular, to a method and apparatus for preserving frame ordering across aggregated links between source and destination nodes.

2. Background Information

As computer technology has evolved, so too has the use of networks which communicatively couple computer systems together allowing remote computer systems to communicate with one another. The improved computer technology, along with the widely distributed nature of corporate computing and the cost/accessibility of high bandwidth data networks has fostered the growth of multi-media network applications over such networks. One example of just such a network topology is the Ethernet standard topology. In recent years, we have seen the Ethernet standard evolve from a 10Mb/S standard to a 100Mb/S standard as we

race towards the 1Gb/S standard. Although the prospect of gigabit Ethernet technology will reduce much of the congestion experienced on current Ethernet LAN implementations, those skilled in the art recognize that the additional bandwidth will quickly be consumed by bandwidth-hungry multimedia applications. Thus, another approach is required to improve the bandwidth efficiency of such networks.

One approach currently being considered is the use of multiple physical data links to facilitate the transmission of information, a method commonly referred to as link aggregation. Those skilled in the art will appreciate that link aggregation is a technique which permits one to treat multiple physical links as one logical link, also commonly referred to as a multiple link trunk (MLT). Link aggregation is the topic of study for the Institute for Electrical and Electronic Engineers (IEEE) 802.3ad study group, which is working to define protocols for the exchange of traffic over multi-link trunks. One of the objectives of the study group is maintaining the ordering of frames. In many network protocols receiving frames out of order is likely to cause confusion. Indeed, the ramifications of processing out of order frames are often unpredictable and thus, undesirable. Similarly, the receipt of duplicate frames can also cause problems in many communication protocols. The typical solution to having received an out-of-order and/or duplicate frame sequence is the retransmission of the entire frame sequence. Given a no-contention network architecture such as, for example, the Ethernet network wherein only one network element may be actively transmitting at a time, the need to retransmit entire frame sequences significantly reduces network efficiency.

To improve the efficiency of such networks, a number of solutions are currently being considered to preserve frame ordering across aggregated links, the so-called multi-link trunk. To date, proposed solutions focus on the transmit side of the communication. One proposed solution, for example, relies on tagging frames with sequence numbers at the transmit side, and

removing the sequence numbers from the frames as the frames are received and promoted. Although this method is currently favored in the technical community as providing an easy resolution of the problem, those skilled in the art recognize that such a solution is a costly one insofar as it involves altering the frame structure. That is, instead of simply routing frames a network bridge or switch, for example, must modify the frames to add the sequence numbers, thereby violating a number of bridging protocols. By violating such bridging protocols, a problem of backward compatibility is created, leaving legacy bridges that are unable of supporting aggregated link communication sessions.

Another problem commonly associated with prior art aggregated link control techniques arises on the transmit side when handling "flows", i.e., a sequence of messages or frames that have the same source, destination and quality of service requirements. Prior art switches identify a flow and queue the frames identified as a flow on a single, particular link. Those skilled in the art will appreciate that queuing a flow through a single link, as done in the prior art, eliminates many of the benefits commonly associated with use of an aggregated link, e.g., maximizing throughput, load balancing, etc. due to the management required to switch the entire flow to another physical link.

Thus a method and apparatus for preserving frame ordering across aggregated links between source and destination nodes is required that does not resort to modification of the frames themselves. Accordingly, a method and apparatus for preserving frame ordering across aggregated links is presented which is unencumbered by the inherent deficiencies and limitations commonly associated with the prior art.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention, a method and apparatus for frame ordering across aggregated links between source and destination nodes is presented. In particular, in accordance with one embodiment of the present invention, a method for preserving frame order across multiple physical links between a source and destination node(s) is presented, the method comprising receiving up to a plurality of indications denoting commencement of frame transmission on a corresponding plurality of communication links, and assigning a pointer value to a record in a buffer for each of said frames based, at least in part, on a relative order in which the indications are received.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawing in which like references denote similar elements, and in which:

Figure 1 illustrates a block diagram of an example data network within which the teachings of the present invention may be practiced;

Figure 2 illustrates a block diagram of an example apparatus incorporating the teachings of the present invention, in accordance with one embodiment of the present invention;

Figure 3 graphically illustrates one example of a media independent interface (MII) suitable for use by the apparatus introduced in **Figure 2**, in accordance with one embodiment of the present invention;

Figure 4 illustrates a flow chart of an example method for preserving frame ordering across an aggregated link incorporating the teachings of the present invention, in accordance with one embodiment of the present invention;

Figure 5 graphically illustrates a timing diagram of MII signaling as data is received at a network interface incorporating the teachings of the present invention, in accordance with one embodiment of the present invention;

Figure 6 illustrates a flow chart of an example method for preserving frame transmission order state information when a flow condition is detected, in accordance with one aspect of the present invention;

Figure 7 illustrates a timing diagram of MII signaling as data is received in a flow condition at a network interface incorporating the teachings of the present invention, in accordance with one embodiment of the present invention;

Figure 8 illustrates a block diagram of a data network including a network interface(s) incorporating the teachings of the present invention which interface to multi-speed communication links, in accordance with one aspect of the present invention;

Figure 9 illustrates a block diagram of a data network including a network interface(s) incorporating the teachings of the present invention which interface to an MLT providing Quality of Service (QoS) features, in accordance with one aspect of the present invention; and

Figure 10 illustrates a flow chart of an example method for improving the transmit efficiency of a network interface incorporating the teachings of the present invention, in accordance with one aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to those skilled in the art that the present invention may be practiced without these specific details. In other instances, well known features are omitted or simplified for clarity.

In alternative embodiments, the present invention may be applicable to implementations of the invention in integrated circuits or chip sets, wireless implementations, switching systems products and transmission systems products. For purposes of this application, the terms switching systems products shall be taken to mean private branch exchanges (PBXs), central office switching systems that interconnect subscribers, toll/tandem switching systems for interconnecting trunks between switching centers, and broadband core switches found at the center of a service provider's network that may be fed by broadband edge switches or access multiplexers, and associated signaling, and support systems and services. The term transmission systems products shall be taken to mean products used by service providers to provide interconnection between their subscribers and their networks such as loop systems, and which provide multiplexing, aggregation and transport between a service provider's switching systems across the wide area, and associated signaling and support systems and services.

Turning to **Figure 1**, a block diagram of an example data network **100** within which the teachings of the present invention may be practiced is presented. More specifically, **Figure 1** is a block diagram depicting a data network **100** in which network device **102** is communicatively coupled to network device **104** via an aggregated link, the so-called multi-link trunk (MLT) **106**. In accordance with the teachings of the present invention, a network device incorporating a network interface endowed with the teachings of the present invention preserves the transmission frame order of a plurality of frames communicated via a plurality of physical links by relying on an indication of the commencement of frame transmission. That is, unlike prior art solutions wherein the frames themselves are tagged with an indication of relative sequence at the transmit node, it will be shown that the present invention relies on standard signaling to determine when frame transmission is commenced, and the frame order is tracked and preserved by the receiving node.

Further, those skilled in the art will appreciate that the present invention for preserving frame ordering is an enabling technology leading to improved transmission techniques, receiver performance and network performance enhancements (e.g., quality of service, multi-speed links, etc.), which are all aspects of the present invention. Finally, those skilled in the art will appreciate that the innovative method of preserving frame order, to be described more fully below, may be practiced within the scope of current network communication protocol standards and specifications, thus enabling a network device endowed with the teachings of the present

invention to interface with legacy network devices. These and other aspects of the present invention will be developed more fully below.

As depicted in the illustrated example embodiment of **Figure 1**, network device **102** is coupled to network device **104** via aggregated link **106**. As described above, an aggregated link or MLT such as MLT **106** is a combination of two or more physical links comprising a single logical communication channel between two network nodes, e.g., network device **102** and network device **104**. Each physical link of MLT **106** communicates data packets (also commonly referred to as frames, datagrams, etc., depending on the OSI level of implementation) between two network devices, irrespective of the other physical links. As described above, many network protocols require that frame ordering be preserved in order to ensure the valid transmission of information between network devices. Accordingly, insofar as the physical links themselves independently communicate frames irrespective of the other links comprising the MLT, the network devices must employ some means of preserving frame ordering. Those skilled in the art will appreciate, from the description to follow, that network interface **103** and/or **105**, relying on signaling already defined within certain network standards, e.g., Ethernet standard 802, preserve frame transmission order state information by capturing the received frames in records of a buffer and assigning pointer values to the records based on order of transmission, thereby overcoming the need of prior art solutions to tag each individual frame with a sequence number at the transmitting node, or sending flows on a particular dedicated link.

With continued reference to data network **100** depicted in **Figure 1**, those skilled in the art will appreciate data network **100** depicting only two nodes has been simplified for ease of explanation and so as to not obscure the teachings of the present invention. That is, those skilled in the art will appreciate that data network **100** is typically comprised of a number of network devices such as, for example, routers, hubs, servers, switches and the like utilized to route data packets through the network to their respective destinations. Thus, data network **100** of **Figure 1** is intended to represent any of a number of alternative network architectures incorporating switches, routers, and the like (not shown) that are commonly used to establish and support data communication between network edge devices such as, for example, network devices **102** and **106**. In this respect, data network **100** may well be a Local Area Network (LAN), a Wide Area Network (WAN) network architecture, and the like. In one embodiment, for example, data network **100** is an Ethernet standard network providing 10Mb/s, 100Mb/s or 1Gb/s data rates. Similarly, except for the innovative method of preserving frame order, optimizing transmission and receiver performance, and other aspects of the present invention, network devices **102** and **106** are intended to represent any of a number of alternative routers, switches, hubs, servers, and the like commonly known within the data networking art.

Having described the operating environment within which the teachings of the present invention may be practiced with reference to **Figure 1**, a block diagram of an example network interface incorporating the teachings of the present invention will be introduced with reference to **Figure 2**.

Turning to **Figure 2**, a block diagram of an example network interface incorporating the teachings of the present invention is depicted. In one embodiment of the present invention, network interface **200** is beneficially introduced to network device **102** and/or network device **104** as network interface **103** and/or **105**, respectively. In accordance with the illustrated example embodiment of **Figure 2**, network interface **200** is communicatively coupled to a data network via a multi-link trunk, e.g., MLT **106**, as well as data terminal equipment (DTE) (not shown) via bus **222**. As shown, network interface **200** is depicted comprising a plurality of physical medium interfaces (PHY) **202, 204, 206** and **208** each coupled to an associated medium access controller **210, 212, 214** and **216**, respectively, which are coupled to a Multiplexer/DeMultiplexer (MUX/DeMUX) **218**, as shown. In accordance with one embodiment of the present invention, MUX/DeMUX **218** is coupled to one or more buffer(s) **220** which may be used as transmit buffers or receive buffers. In accordance with one embodiment of the present invention, the number of physical medium interfaces **202-208** corresponds to the number of physical links comprising the multi-link trunk **106**, and the number of MACs **210-216** correspond to the number of PHYs **202-208**. Accordingly, the MUX/DeMUX **218** multiplexes frames to/from the plurality of physical links of MLT **106** via a corresponding MAC and PHY.

As defined herein, the physical medium interface (PHY) **202-208** provides the physical and electrical interface between network interface **200** and the multi-link trunk **106** using any of a number of medium attachment units (MAU) known in the art (e.g., tap connector, BNC "T", and the like). In one embodiment, PHY **202-208** is responsible for encoding/decoding data in

accordance with the transmission protocol of MLT **106**. That is, in its function as a receiver, PHY **202-208** decodes an encoded transmission received from a physical link of MLT **106** for presentation to MAC **210-216**, and the DTE respectively. Conversely, in its function as transmitter, PHY **202-208** encodes frames received from the DTE by way of MAC **210-216** for transmission via a corresponding physical link of MLT **106**. In one embodiment, PHY **202-208** employs a Manchester encoder/decoder. In an alternate embodiment, PHY **202-208** employs a Viterbi encoder/decoder. In yet another embodiment, an 8B/10B encoding scheme is employed to facilitate gigabit Ethernet over fiber. Irregardless of the encoding technique employed, PHY **202-208** employs a media independent interface (MII) protocol to communicate with MAC **210-216**. Those skilled in the art will appreciate that the MII defines a set of communication signals and protocols for communication between MAC **202-208** and PHY **210-216**, respectively. That is, MII enables MACs to communicate with any of a number of alternate PHYs adhering to the MII protocol. One example of an MII between MAC **202-208** and PHY **210-216** is depicted with reference to **Figure 3**.

Turning, briefly, to **Figure 3** an example media independent interface (MII) **306** is shown coupling physical medium interface **302** with media access controller **304**. As depicted, MII **306** is comprised of a number of receive signals, transmit signals and control signals. In accordance with the illustrated example embodiment of **Figure 3**, MII **306** is shown comprising receive clock (RX_CLK) **308**, receive error (RX_ERR) **310**, receive data valid (RX_DV) **312**, receive data (RX_D) **314**, carrier sense (CRS) **316**, transmit data (TX_D) **318**, transmit error (TX_ER)

320, transmit enable (TX_EN) **324** and transmit clock (TX_CLK) **326** signals. As used herein, the label of transmit and receive are relative to MAC **304**, thus, RX_D signal **314** provides data transmitted from PHY **302**. In one embodiment, RX_D signal **314** is a nibble-wide (e.g., four bit) signal, while in an alternate embodiment, RX_D signal **314** an eight-bit (e.g., an octet wide) signal.

Except as used in accordance with the teachings of the present invention, to be described more fully below, the function of each of the MII signals **308-326** of are generally well known in the art and, thus, need not be further described here. Of particular interest with respect to the teachings of the present invention, however, is the receive data valid signal RX_DV **312**. Those skilled in the art will appreciate that RX_DV signal **312** is asserted by PHY **302** to indicate that valid data decoded from the physical medium is being presented on RX_D **314**. More specifically, PHY **302** asserts RX_DV signal **312** to denote to MAC **304** that frame transmission has commenced, and that the frames presented on RX_D **314** are valid (e.g., do not contain errors). In accordance with the teachings of the present invention, RX_DV **312** is asserted any time during or immediately after a preamble of the transmitted frame. That is, the RX_DV signal **312** provides an indication to the MAC that frame transmission has commenced on a physical link associated with the PHY asserting the RX_DV signal. In accordance with one embodiment of the present invention, the RX_DV signal **312** is an analog signal that is asserted upon detecting valid data, and remains asserted throughout transmission of the frame. Thus, in accordance with the teachings of the present invention to be developed more fully below,

network interface **200** utilizes the indication provided by the assertion of RX_DV signal **312** associated with each PHY to determine frame transmission order.

Returning to the illustrated example embodiment of **Figure 2**, MACs **210-216** interface the data terminal equipment (DTE) with data network **100** via the physical interface (PHY) **202-208**. Accordingly, MACs **210-216** transmit and receive messages to/from the DTE, perform message encapsulation and control (framing, addressing, synchronization, error detection, etc.) as well as media access management functions (collision avoidance, contention resolution, etc.). In accordance with the illustrated example embodiment of **Figure 2**, a single MAC (e.g., MAC **210**) is associated with a single PHY (e.g., PHY **202**) and corresponding physical link of the MLT. In accordance with the illustrated example embodiment of **Figure 2**, MACs **210-216** are coupled to MUX/DeMUX **218**. As will be described in greater detail below, the MUX/DeMUX layer **218** receives frames of information to be transmitted from the DTE in a transmit buffer **220** and distributes the frames to MACs **210-216**. Conversely, MUX/DeMUX **218** receives decoded frames received from MACs **210-216** and promotes them from a receive buffer **220** to a system state at the DTE in a serialized manner via bus **222**. Those skilled in the art will appreciate, from the description to follow, that MUX/DeMUX **218** may well be found in any of a number of alternate forms with alternate names. In one embodiment, for example, the function of MUX/DeMUX **218** is embodied in a logical MAC (LMAC) supporting a plurality of physical MACs (PMAC), e.g., MAC **210-216**. In an alternate embodiment, the MUX/DeMUX function is embodied in an aggregated MAC (AMAC) supporting a plurality of physical MACs. Those

skilled in the art will recognize that, although different in name, the teachings of the present invention may be practiced an a variation of forms without deviating from the spirit and scope of the present invention.

In accordance with the teachings of the present invention, the order in which a received frame is promoted from receive buffer **220** corresponds to the relative order in which the RX_DV signal **312** associated with the particular frame is received. In one embodiment, to be described more fully below, further optimization of the receive function can be achieved by detecting "flow" conditions. That is, in accordance with one aspect of the present invention, network interface **200** identifies a flow condition, and allocates specific resources (e.g., receive buffers, pointer buffers, etc.) to handle the flow, thereby reducing the processing required to ensure frame ordering.

Having introduced an example operating environment, hardware architecture and communication interface associated with the teachings of the present invention with reference to the block diagrams of **Figures 1** through **3**, attention is now directed to **Figure 4** wherein a flow chart of an example method for preserving frame ordering is presented, in accordance with one embodiment of the present invention. For ease of explanation, and not limitation, the example embodiment of **Figure 4** will be developed with continued reference to **Figures 1-3**, wherein network device **102** is the source node utilizing a number of physical links of MLT **106** to communicate with network device **104**, the destination node.

Turning to the method of **Figure 4**, the method begins with source node **102** commencing transmission of up to a plurality of frames over a plurality of physical links comprising MLT **106**. Upon detecting the commencement of frame transmission on any of the physical links comprising MLT **106**, the PHY **202-208** of the destination node network interface **105** corresponding to the physical link with transmission activity asserts an RX_DV signal **312**. That is, once PHY **202**, for example, detects valid data transmission via a corresponding physical link, PHY **202** asserts an RX_DV signal **312**, i.e., an indication of the commencement of frame transmission, to MAC **210** at **402** denoting that valid receive data is being received on RX_D **314**. As MAC **210** receives the RX_DV signal **312**, it provides an indication to MUX/DeMUX **218** of the incoming frame which generates a pointer in a pointer buffer **220** associated with the frame, **404**. MAC **210** receives the transmitted frame (a nibble, byte, word, etc. at a time) via RX_D **314**. Consequently, by generating a pointer list associated with the assertion of RX_DV signals, MUX/DeMUX **218** preserves the state of frame transmission order without unnecessarily modifying the content of the transmitted frames as done in the prior art. At **406**, a determination is made of whether the incoming frame is completely received. If not, a further determination is made at **408** of whether another incoming frame has been detected on another physical link. If so, the process continues with **402** as the next frames are received, otherwise, the process continues with block **406** until the frame is completely received.

Once a frame is completely received, a determination is made as to whether the received frame corresponds to the first pointer value in the pointer buffer, **410**. If not, the frame is stored

to the next available record in the receive buffer, **412**. If, however, the received frame does correspond to the first pointer value in the pointer buffer, the frame is promoted to the system state at the DTE, and the pointer buffer is incremented to the next pointer value record, **414**. At **416**, MUX/DeMUX **218** determines whether the pointer buffer is empty and, if so, the process returns to block **402**. If the pointer buffer is not empty, the process continues at **418** wherein MUX/DeMUX **218** determines whether the frame corresponding to the next pointer value record in the pointer buffer has been completely received. If not, the process continues with block **406**. If, however, MUX/DeMUX **218** determines that the frame corresponding to the next pointer value in the pointer buffer has been received, the process continues with block **414**.

Although discussed above as separate buffers, those skilled in the art will appreciate that the pointer values and the frames themselves may well be stored in a common buffer without deviating from the spirit and scope of the present invention. That is to say that the innovation of preserving state information of the order of frame transmission on the receive side by relying on network standard signaling which denotes the commencement of frame transmission, assigning a pointer value to identify the received frame, and then promoting the frames to a system state in order of pointer value may well be practiced in many different forms in many different network architectures/topologies without deviating from the spirit and scope of the present invention. Accordingly, such embodiments are anticipated by the teachings of the present invention.

Having described an example architecture and method of certain embodiments of the present invention above, it may be helpful to illustrate the operation of the present invention in

terms of a timing diagram, such as that presented in **Figure 5**. That is, **Figure 5** provides a timing diagram depicting RX_DV **312** and RX_D **314** for three (3) physical links (A, B, and C), along with a graphical illustration of an example pointer buffer and an example receive buffer, respectively.

In accordance with the illustrated embodiment of **Figure 5**, transmission from source node **102** begins on physical link C as denoted by the assertion of RX_DV_C **510** at position **514**. As described above, the assertion of RX_DV_C **510** denotes that a valid frame (C_1) is being received on RX_D_C **512**. Thus, in accordance with the teachings of the present invention, a pointer to frame C_1 is placed in pointer value buffer **538**. As frame C_1 is being received, an indication is received in the form of RX_DV_A **502** that a valid frame (A_1) is being received on RX_D_A **504** at position **516**. As above, in accordance with the teachings of the present invention, a pointer to frame A_1 is placed in a subsequent record of pointer value buffer **538**. Further, as frame C_1 is being received, an indication is received in the form of RX_DV_B **506** that a valid frame (B_1) is being received on RX_D_B **508** at position **518**. In accordance with the teachings of the present invention, a pointer associated with frame B_1 is stored in a subsequent record of pointer buffer **538**.

Continuing along the timing diagram, at position **520**, as frames B_1 and A_1 are still being received via their respective links, frame C_1 is completely received without receiving an error (e.g., RX_ER). In accordance with the teachings of the present invention, insofar as the pointer to frame C_1 resides atop pointer buffer **538** it is promoted to a system state at the DTE once it is

completely received. As the pointer value to frame C_1 is promoted from pointer buffer **538**, the pointer associated with frame A_1 now resides atop pointer value buffer. At position **522**, frame B_1 is completely received and stored in a subsequent record of receiver buffer **540**, as shown. However, in accordance with the teachings of the present invention, frame B_1 is not promoted until frame A_1 has been promoted, insofar as the pointer value for frame A_1 has a higher priority within the pointer buffer.

At position **524**, while frame A_1 is still being received, an indication is received from RX_DV_B **506** that a valid frame (B_2) is being received via RX_D_B **508**. Thus, in accordance with the teachings of the present invention, a pointer value corresponding to frame B_2 is placed in a subsequent record of pointer buffer **538**. While frame B_2 is being received, an indication is received from RX_DV_C **510** at position **526** that a valid frame (C_2) is being received via RX_D_C **512**. Accordingly, a pointer value corresponding to frame C_2 is placed in a subsequent record of pointer value buffer **538**. At position **528**, while A_1 and C_2 are being received, frame B_2 is completely received without indication of error and is stored in a subsequent record of receive buffer **540**, as depicted. As above with respect to frame B_1, although frame B_2 has been completely received, it cannot be promoted to the upper layer until frames A_1 and B_1 are promoted.

Subsequently, while frames A_1 and C_2 are being received, an indication is received in the form of RX_DV_B **506** that a valid frame (B_3) is being received on RX_D_B **508** at position **530**. In accordance with the teachings of the present invention, a pointer value to frame B_3 is placed in

a subsequent record of pointer value buffer **538**, as depicted. At position **534**, while frames A_1 and C_2 are still being received, frame B_3 is completely received without indication of error, and is stored to a subsequent record of receive buffer **540**, as shown. As above, frame B_3 cannot be promoted until the frames corresponding to pointer values ahead of the pointer value corresponding to B_3 are promoted. At position **532**, frame C_2 is completely received without indication of error and is stored to a subsequent record of receive buffer **540**, as shown. Finally, at position **536**, frame A_1 is completely received without indication of error and is stored in a subsequent record of receive buffer **540** as shown.

In accordance with the teachings of the present invention, since the pointer to frame A_1 is at the top of pointer buffer **538** once the frame is completely received at position **536**, it is promoted to a system state with DTE. Further, since frames B1, B2, C2 and B3 have also been previously received and stored within receive buffer **540**, they are similarly promoted in the order in which frame transmission commenced, as denoted in pointer buffer **538**.Thus, rather than altering the content of the frame to denote a sequence number as done in the prior art, a network interface employing the teachings of the present invention relies on an indication of the commencement of frame transmission to preserve the state of frame order transmission. That is, frames are promoted to upper layers in order of frame transmission as recorded by the receiving node relying on standard signaling denoting the commencement of frame transmission.

Having described a method and apparatus for preserving the order of frame transmission above with reference to **Figures 1-5**, a flow chart of an example method for improving the

receive performance of a network interface is depicted in **Figure 6**, in accordance with one embodiment of the present invention. With reference to **Figure 6**, a network interface incorporating the teachings of the present invention, e.g., network interface **300**, receives up to a plurality of indications denoting the commencement of frame transmission over an MLT, **602**. At **604**, a determination is made as to whether the received frames constitute a subset of a flow, i.e., a sequence of messages that have the same source, destination and quality of service requirements. In one embodiment, the DeMUX layer **218** identifies a flow by analyzing control information embedded within a frame to identify the source, destination, quality of service, and other similar information. If, at **604**, it is determined that the received frames do not constitute a flow, the method proceeds to assign pointer values and store received frames until they can be promoted, on a per frame basis, as described above with reference to **Figure 4**, at **606**.

Alternatively, if a flow is detected at **604**, DeMUX layer **218** allocates specific resources to enable the frames to be processed through to the DTE without further re-ordering at the network interface, **608**. That is, recognizing that some protocols are not adversely impacted by out of order transmission (e.g., certain implementations of TCP/IP), the DeMUX layer **218** identifies such frames and passes them through to the DTE without regard to frame order, thereby increasing the receive forwarding rate and reducing the processing associated with buffering such frames. As described above with reference to **Figure 4**, a determination is made at **610**, on a per frame basis, of whether transmission is complete or the pointer buffer is empty. If transmission on a per frame basis is complete, frames are read from the receive buffer as

described above in **Figure 4**, **612**. Alternatively, if transmission is not complete, a further determination is made, **611**, of whether frame transmission on another physical link has been detected. If transmission of another frame has commenced, the process continues with block **602**, while transmission of the former frame is completed. If, however, no addition indications of frame commencement are received, the process continues with bloc **610** until the frame is completely received.

At **614**, a determination is made by MUX/DeMUX **218** of whether the pointer buffer is empty and, if so, the process continues with block **602**, as the MUX/DeMUX **218** awaits further indication(s) of the commencement of frame transmission via MLT **106**. Alternatively, if the pointer buffer is not complete, the process returns to block **612** as the next record is read from the receive buffer and promoted to the DTE, as described above.

Thus, in accordance with one aspect of the present invention, a network interface incorporating the teachings of the present invention enhances the receive efficiency of a flow by determining whether the flow is sensitive to out-of-order frame sequences and, if not, passes the frames directly through to the DTE without the need of buffering. Expanding on the teachings of the present invention, described above, an improved method for handling flows is now presented, in accordance with another aspect of the present invention. That is, in accordance with one aspect of the present invention, a destination node incorporated with the teachings of the present invention, e.g., network device **104**, creates and maintains a separate pointer buffer dedicated to each detected flow, while continuing to utilize a common receive buffer. In accordance with this

aspect of the present invention, all frames associated with a particular flow have pointers set up in a dedicated pointer buffer in the order in which frame transmission commenced. When a frame has been completely received at the receiver, if it is the first pointer in a particular pointer buffer, it is passed to the upper layer without regard to the frames associated with other pointer buffers. By maintaining separate pointer buffers (or link lists) for each flow, frames from one flow do not have to wait for frames from other flows to arrive before they are promoted to an upper layer. Those skilled in the art will appreciate that a further advantage of the present invention is that is a physical link were to go down, the frames can be distributed on the remaining links without the need to flush transmit queues before transmission can resume. A timing diagram illustrating this aspect of the present invention is presented with reference to **Figure 7**.

Turning to **Figure 7**, a timing diagram of illustrating the RX_DV signals **702, 706, 710** and RX_D **704**, **708**, **712** signals for three physical links (1, 2 and 3) are depicted. In addition, **Figure 7** also depicts pointer buffers **714**, **716** and **718** created upon the detection of flows A, B and C, respectively, and receive buffer **720**. As shown in **Figure 7**, individual pointer values are assigned to frames upon receiving an indication of the commencement of frame transmission and determining whether the incoming frame corresponds to a flow. In one embodiment, a minimal amount of data must first be received before it is determined that the incoming frame is associated with a particular flow, before a pointer value is assigned to the incoming frame. In an alternate embodiment, however, a pointer value is assigned based, at least in part, on a physical

link upon which a known flow condition is present. In addition, frames are promoted from receive buffer **720** in pointer value order, as stored in pointer buffers **714, 716** and **718**. Thus, frames B_1 and C_1 are immediately promoted upon receipt without regard to frame A_1. A_2, however, must wait until frame A_1 has been completely received and promoted before it may be promoted, in accordance with the teachings of the present invention described above. In this way, the load balancing and efficient transmission characteristics commonly associated with aggregated link technology can be realized, while preserving the state of frame transmission order for a plurality of identified flows, without resorting to dedicated links, or altering the frame to denote transmission sequence.

A further aspect of the present invention is illustrated with reference to the network depicted in **Figure 8**. As depicted in **Figure 8**, network device **102** having network interface **103** is communicatively coupled to network device **104** having network interface **105** via MLT **106**, much as in **Figure 1**. In accordance with this aspect of the present invention, however, the physical links of the MLT **106** are split into high-speed links **802** and low-speed links **804**. As depicted, high-speed links **802** are comprised of physical links **806, 807** and **808**, while low speed links are depicted as **810** and **811**. In accordance with this aspect of the invention, a network interface incorporating the teachings of the present invention (e.g., network interface **103** and/or network interface **105**) creates a separate pointer buffer for the high-speed links **802** and the low speed links **804**. That is, as shown in **Figure 8**, a network interface incorporating the teachings of the present invention, employs high-speed pointer buffer **812** and low-speed pointer

buffer **814** to maintain separate link lists of pointers values corresponding to frames stored in receive buffer **816**. In accordance with this aspect of the present invention, frames are promoted from receive buffer **816** in order of pointer value with priority given to pointer values in high-speed pointer buffer **812** over low-speed pointer buffer **814**. In one embodiment, for example, frames corresponding to pointer values residing in low-speed pointer buffer **814** are not promoted until high-speed pointer buffer **812** is completely empty, i.e., receive buffer **816** is void of any frames received via one of high-speed links **802**.

Extending this concept further, another aspect of the present invention emerges as the teachings of present invention preserve the state of frame transmission order enabling Quality of Service (QoS) features. As depicted in **Figure 9**, network device **102** with network interface **103** is communicatively coupled to network device **104** with network interface **105** via MLT **106** offering physical links associated with three distinct QoS priority levels. More specifically, MLT **106** offers a high priority QoS link **902**, a medium priority QoS link **904** and a low priority QoS link **906**. In accordance with the teachings of the present invention, described more fully above, a network interface incorporating the teachings of the present invention, e.g., **103** and/or **105**, establishes a pointer buffer for each of the QoS links **902-906**. That is, in accordance with the teachings of the present invention, a high priority QoS pointer buffer **908**, a medium priority QoS pointer buffer **910** and a low priority QoS pointer buffer **910** are established to preserve the state of frame transmission order of received frames. In one embodiment of the present invention, frames are promoted to the DTE from receive buffer **914** in order of pointer value, with priority

given to high priority QoS pointer buffer **908**, while frames associated with pointer values are promoted from medium and low priority QoS pointer buffers **910** and **912**, once higher priority frames have been processed.

Given the foregoing discussion associated with **Figures 1-9**, those skilled in the art will appreciate that a number of different aspects and embodiments of the present invention have been introduced. Although developed in the context of example embodiments, those skilled in the art will appreciate that the scope of the present invention is not so limited. For example, in addition to preserving frame transmission order state information at the receive side, those skilled in the art will appreciate that the teachings of the present invention may well be applied to improving the transmission characteristics of a network interface incorporating the teachings of the present invention. That is, in accordance with yet another aspect of the present invention, transmit performance is improved through transmit queue optimization of an appropriately configured network interface, e.g., network interface **103** and/or network interface **105**.

Turning to **Figure 10**, a flow chart of an example method for enhancing the transmit efficiency of a network device incorporating the teachings of the present invention is depicted, in accordance with one aspect of the present invention. As depicted in **Figure 7**, the method begins wherein MUX **218** receives frames from the DTE for transmission over MLT **106** of data network **100**, **1002**. At **1004**, MUX **218** identifies the transmit performance attributes of each of MACs **210-216**. In accordance with one aspect of the present invention, instead of simply alternating through MACs **210-216** in a round-robin fashion queuing frames to be transmitted,

MUX **218** makes a qualitative determination of how loaded each of the MACs **210-216** are. In one embodiment, for example, MUX **218** employs a counter to determine the amount of data queued in each MAC **210-216** for transmission, and performs load balancing accordingly. In an alternate embodiment, wherein multi-speed links are employed in MLT **106**, MUX **218** employs a counter to determine the amount of data queued in each MAC **210-216** and multiplies this value by the known speed of each link to calculate a loading value for each queue. Given the loading value for each queue, MUX **218** balances the among each MAC **210-216** accordingly. In yet another embodiment, MUX **218** detects a flow condition (as described above) coming from a DTE and directs all frames associated with the flow to a MAC designated as having the least queue depth, thereby minimizing frame delays.

Having identified the transmit performance attributes of each MAC **210-216**, MUX **218** further determines whether the frames received from the DTE require a particular priority level of service, e.g., Quality of Service (QoS) level, **1006**. If not, MUX **218** performs load balancing of the frames to be transmitted, balancing the frames across available MACs **210-216** in accordance with the identified transmit performance attributes of the MACs **210-216**, **1008**.

Alternatively, if a particular QoS is requested at block **1006**, MUX **218** makes a further determination of whether the QoS can be supported, **1010**. If not, MUX **218** prompts the DTE as to whether to continue transmission of the frames on a best-effort basis **1012**. If so, MUX **218** performs load balancing across the MACs **210-216** in accordance with the identified transmit

performance attributes **1008**. If the DTE does not accept the offer of best effort transmission at **1012**, MUX **218** denies the transmit request of the DTE and the process ends.

If, at block **1010**, the requested QoS can be supported, MUX **218** performs load balancing to achieve the desired QoS, block **1014**. In one embodiment, for example, MUX **218** prioritizes the frames ahead of other frames to ensure that the requested QoS is met. In an alternate embodiment, MUX **218** dedicates transmission resources to ensure that the requested QoS is achieved.

While various aspects and alternate embodiments of the present invention have been described above, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. In particular, the present invention may be practiced with other features and/or feature settings. Particular examples of other features include but are not limited to transaction communication protocols and architectural attributes. Accordingly, the description is to be regarded as illustrative instead of restrictive on the present invention.

Thus, alternative methods and apparatus for preserving frame ordering across aggregated links between a source and destination node has been described.

CLAIMS

What is claimed is:

1. A method for preserving frame order of a plurality of frames transmitted over a plurality of communication links, the method comprising:

(a) receiving up to a plurality of indications denoting the start of frame transmission on a corresponding plurality of communication links; and

(b) assigning a pointer value to each of a plurality of records in a buffer receiving the corresponding plurality of frames based, at least in part, on a relative order in which the indications are received.

2. The method of claim 1, further comprising:

reading the received frames out of the buffer based, at least in part, on the pointer value.

3. The method of claim 2, wherein the frames are read out of the buffer in an increasing pointer value order.

4. The method of claim 1, wherein the indication is an analog indication.

5. The method of claim 4, wherein the data network is an Ethernet network and the indication is a receive data valid (RX_DV) signal.

6. The method of claim 1, wherein the plurality of frames are a plurality of frame sizes.

7. The method of claim 1, wherein the buffer order does not correspond to the order of frame transmission.

8. The method of claim 1, wherein the plurality of frames are read out of the buffer in accordance with their pointer value, which is different than the order in which the frames are stored in the buffer.

9. An apparatus comprising:

a buffer having a plurality of records; and

a network interface, coupled to the buffer, to receive a plurality of frames from a plurality of communication links, to store the frames in a corresponding plurality of records within the buffer in order of receipt, and to assign a pointer value to each of the plurality of records denoting a relative order of frame transmission of each of the plurality of frames.

10. The apparatus of claim 9, wherein the network interface receives, for each of the plurality of communication links, an indication denoting the commencement of frame transmission to assign the pointer value.

11. The apparatus of claim 9, wherein the plurality of communication links are part of an Ethernet network.

12. The apparatus of claim 9, wherein the indication is an analog indication.

13. The apparatus of claim 12, wherein the indication is an asserted receive data valid signal.

14. The apparatus of claim 9, wherein the network interface promotes frames stored in the plurality of records of the buffer to a system state in order of pointer value.

15. In a data network, a method for preserving frame order of a plurality of frames transmitted across a multi-link trunk, the method comprising:

(a) receiving up to a plurality of indications denoting commencement of frame transmission on the multi-link trunk; and

(b) assigning a plurality of pointer values to a corresponding plurality of records in a buffer receiving the corresponding plurality of transmitted frames based, at least in part, on a relative order in which the indications are received.

16. The method of claim 15, wherein the multi-link trunk is comprised of a plurality of physical links aggregated as a single logical link.

17. The method of claim 15, wherein the indications are an analog signal denoting receive data valid.

18. The method of claim 15, further comprising promoting the received frames from the buffer based on pointer value order.

19. A network device to communicate with other network devices through a multi-link trunk, the network device comprising:

a buffer having a plurality of records; and

a network interface, coupled to the buffer and the multi-link trunk, to receive a plurality of data frames from the multi-link trunk, store the frames in a corresponding plurality of records

in the buffer, and to assign a pointer value to each of the plurality of records denoting the relative order of frame transmission commencement of each of the plurality of frames.

20. The network device of claim 19, wherein the multi-link trunk is comprised of a plurality of physical links.

21. The network device of claim 20, wherein the network interface receives, for each of the plurality of physical links comprising the multi-link trunk, an indication denoting the commencement of frame transmission on each physical link, and uses the indication to assign pointer values.

22. The network device of claim 19, wherein the network interface promotes each of the plurality of frames stored in the buffer to a system state in order of pointer value, irregardless of an order in which they are stored in the buffer.

ABSTRACT OF THE DISCLOSURE

A method for preserving frame order of a plurality of frames transmitted over a plurality of communication links is presented. In accordance with the teachings of the present invention, the method includes receiving up to a plurality of indications denoting commencement of frame transmission on a corresponding plurality of communication links, and assigning a pointer value to a record in a buffer for each of said frames based, at least in part, on a relative order in which the indications are received.

FIG. 1

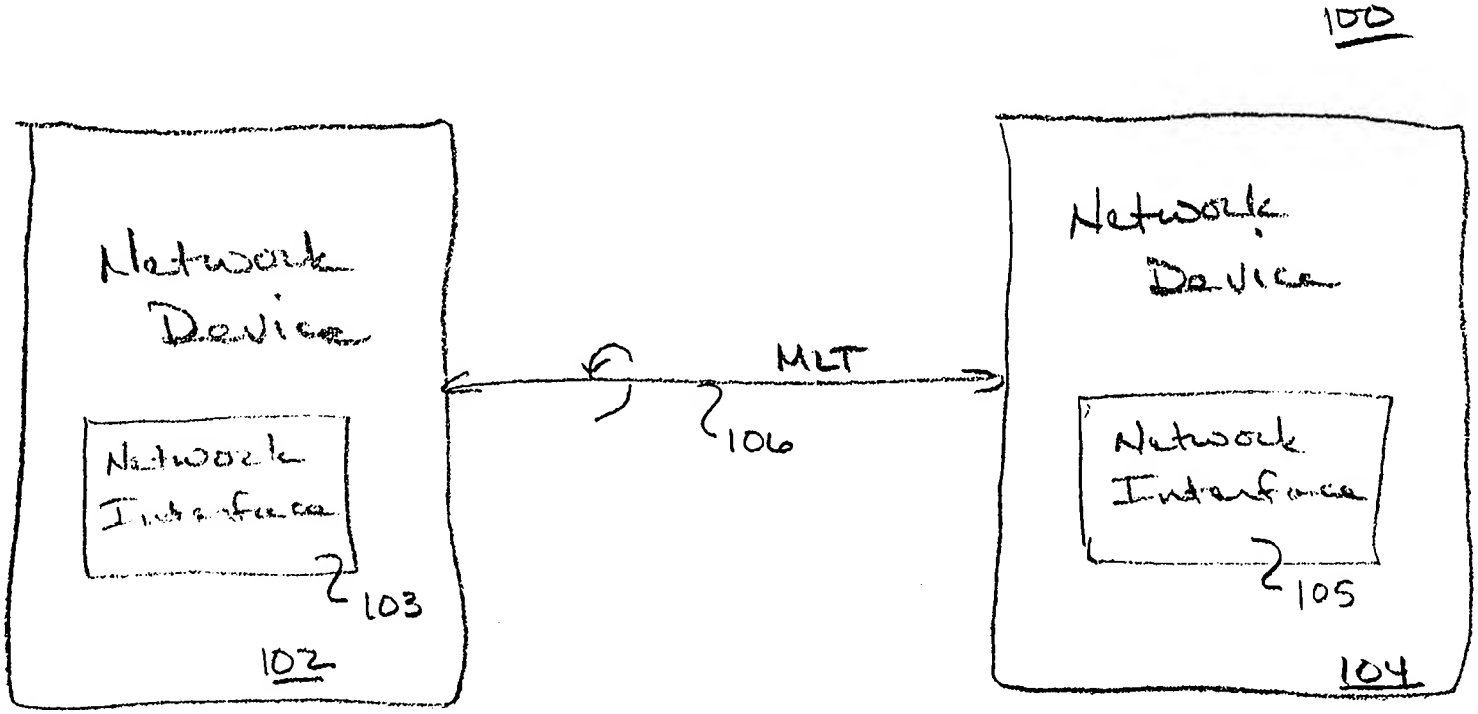
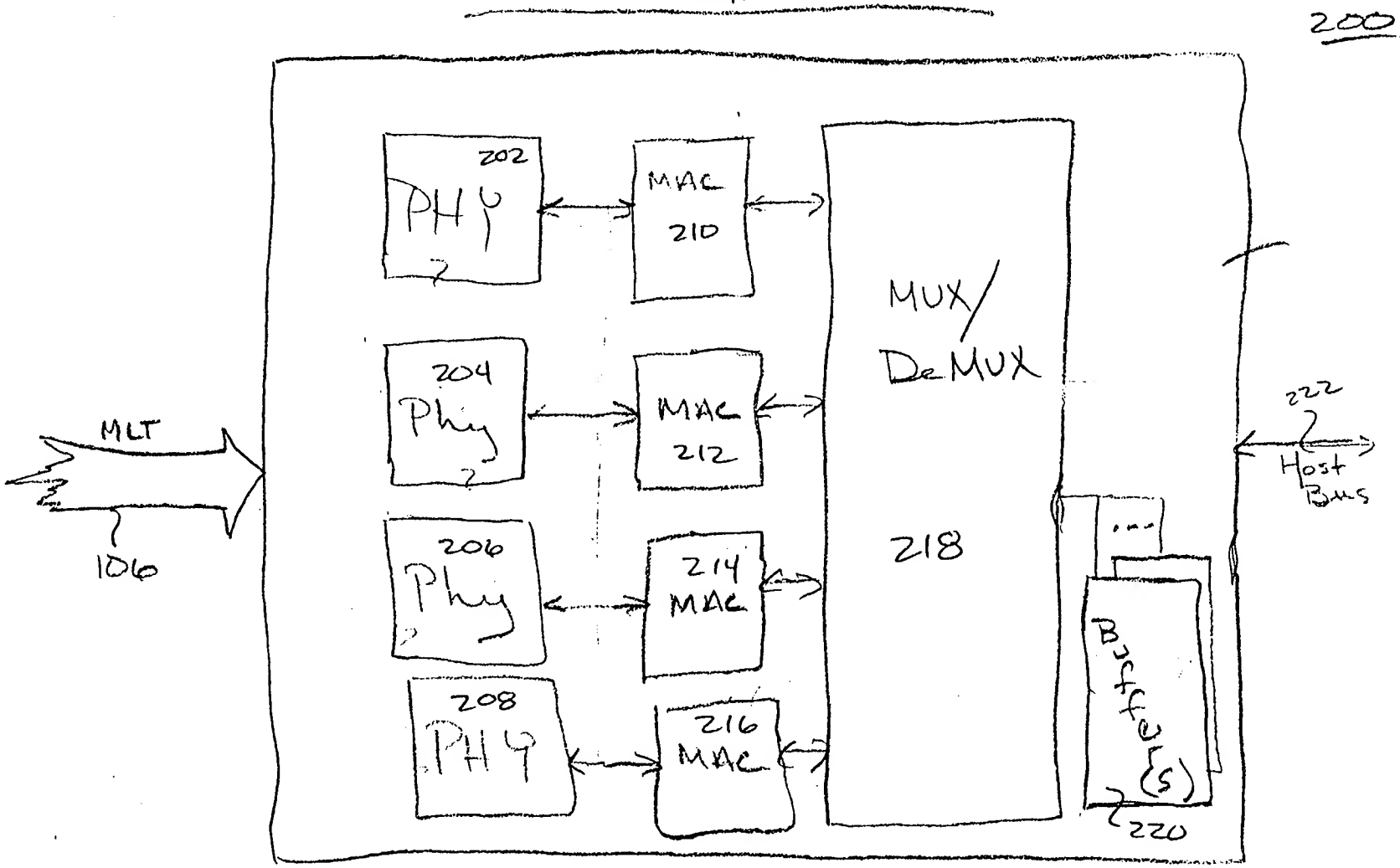


FIG. 2



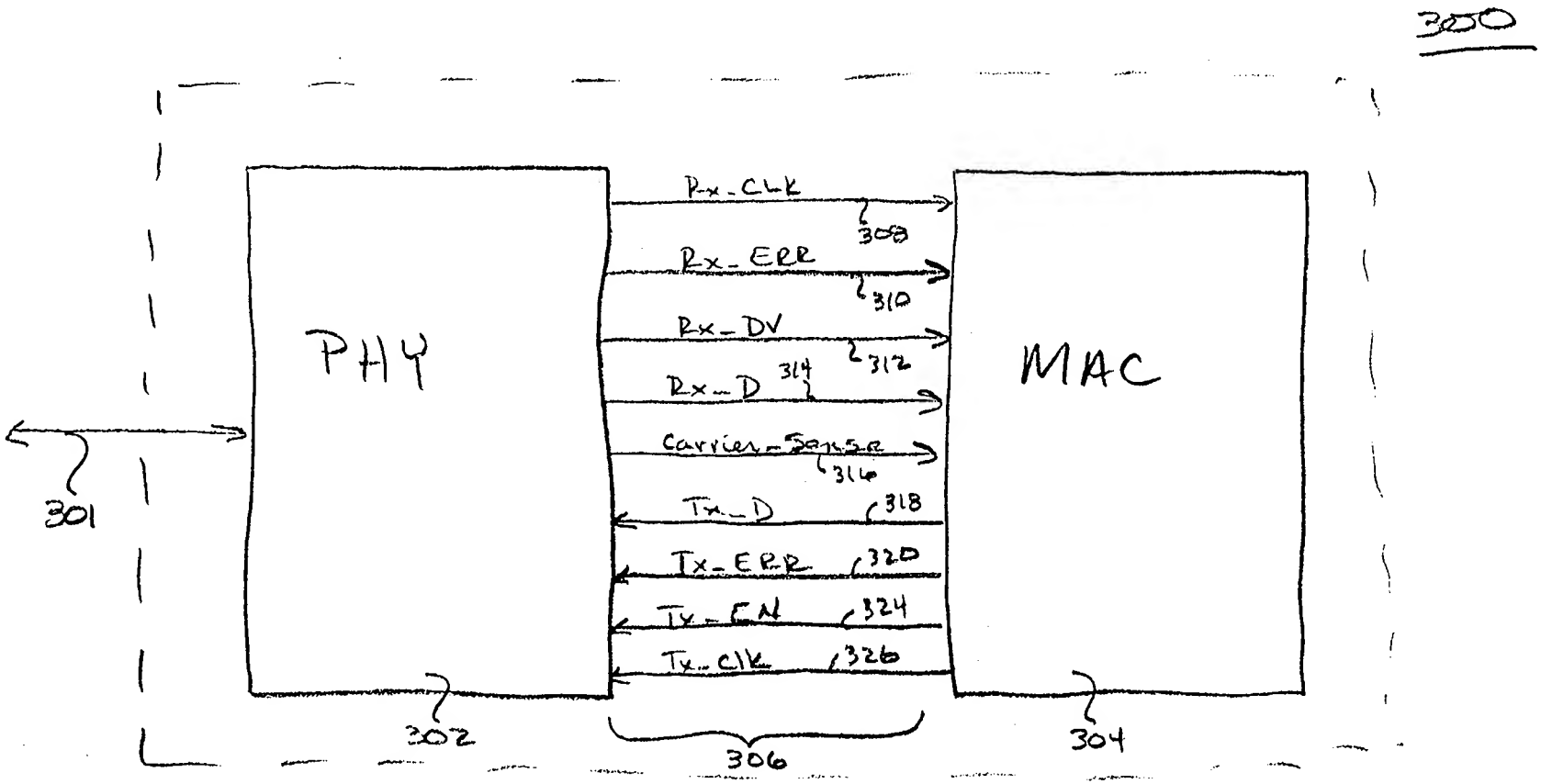


FIG. 3

FIG. 4

400

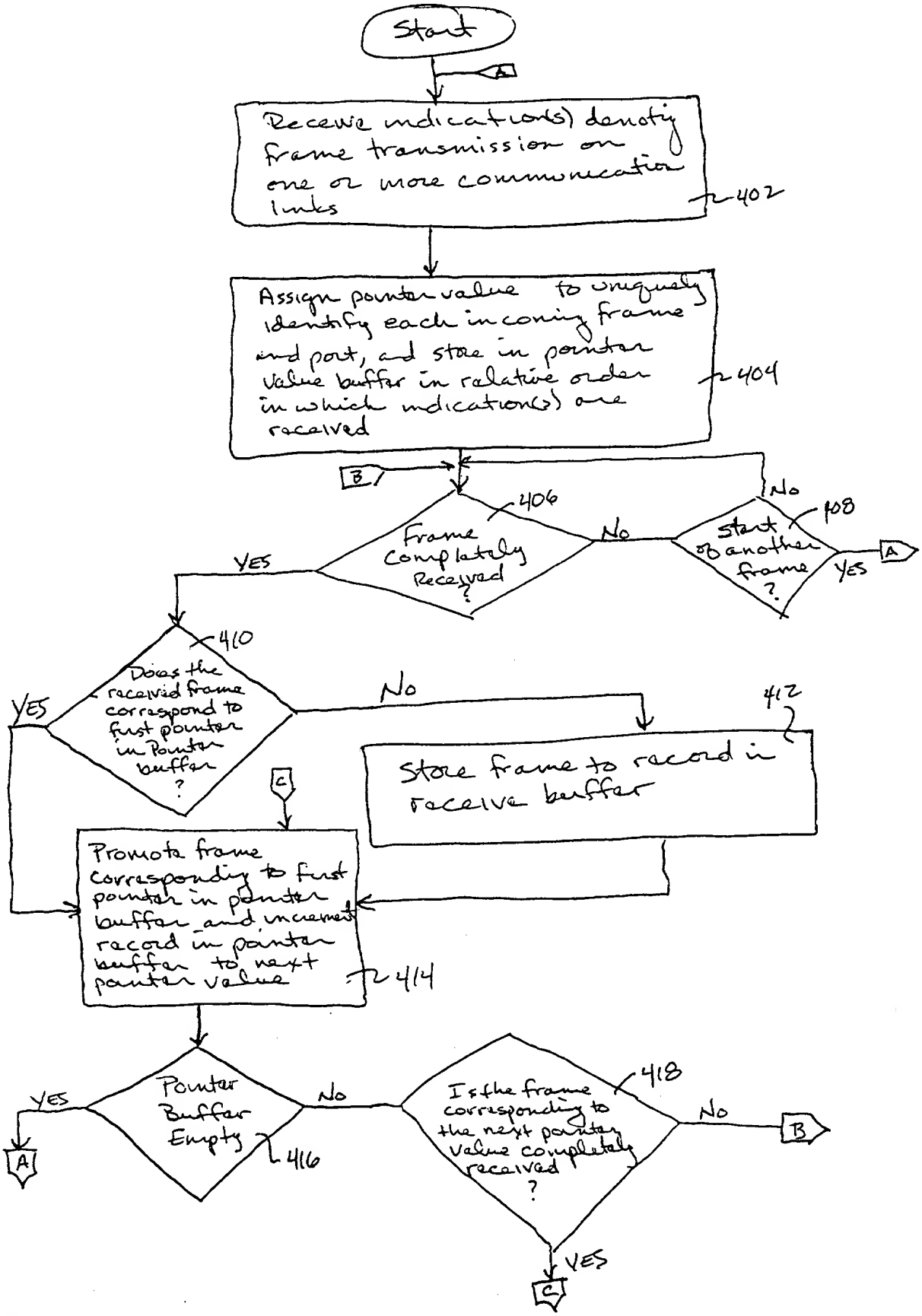
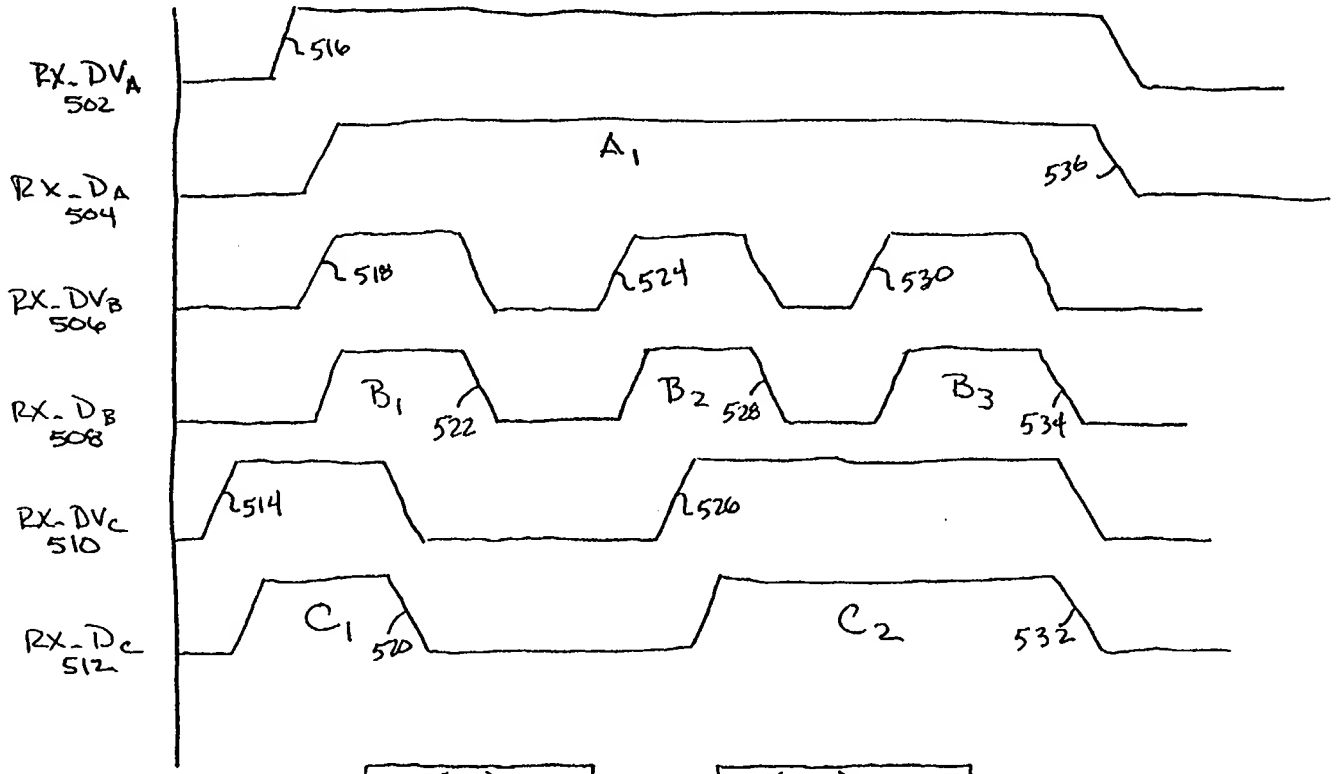
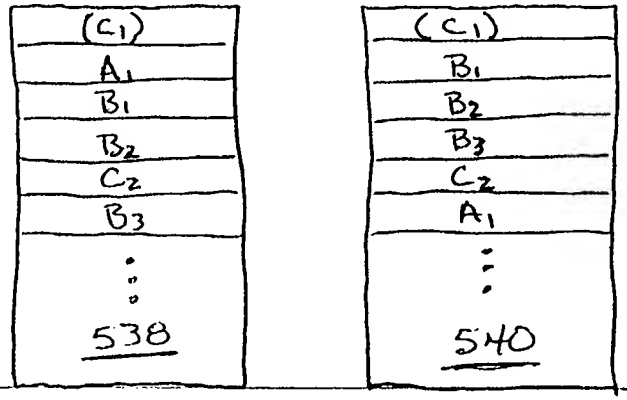


FIG. 5





(C1) Denotes frame C1 promoted upon complete receipt.

FIG. 6

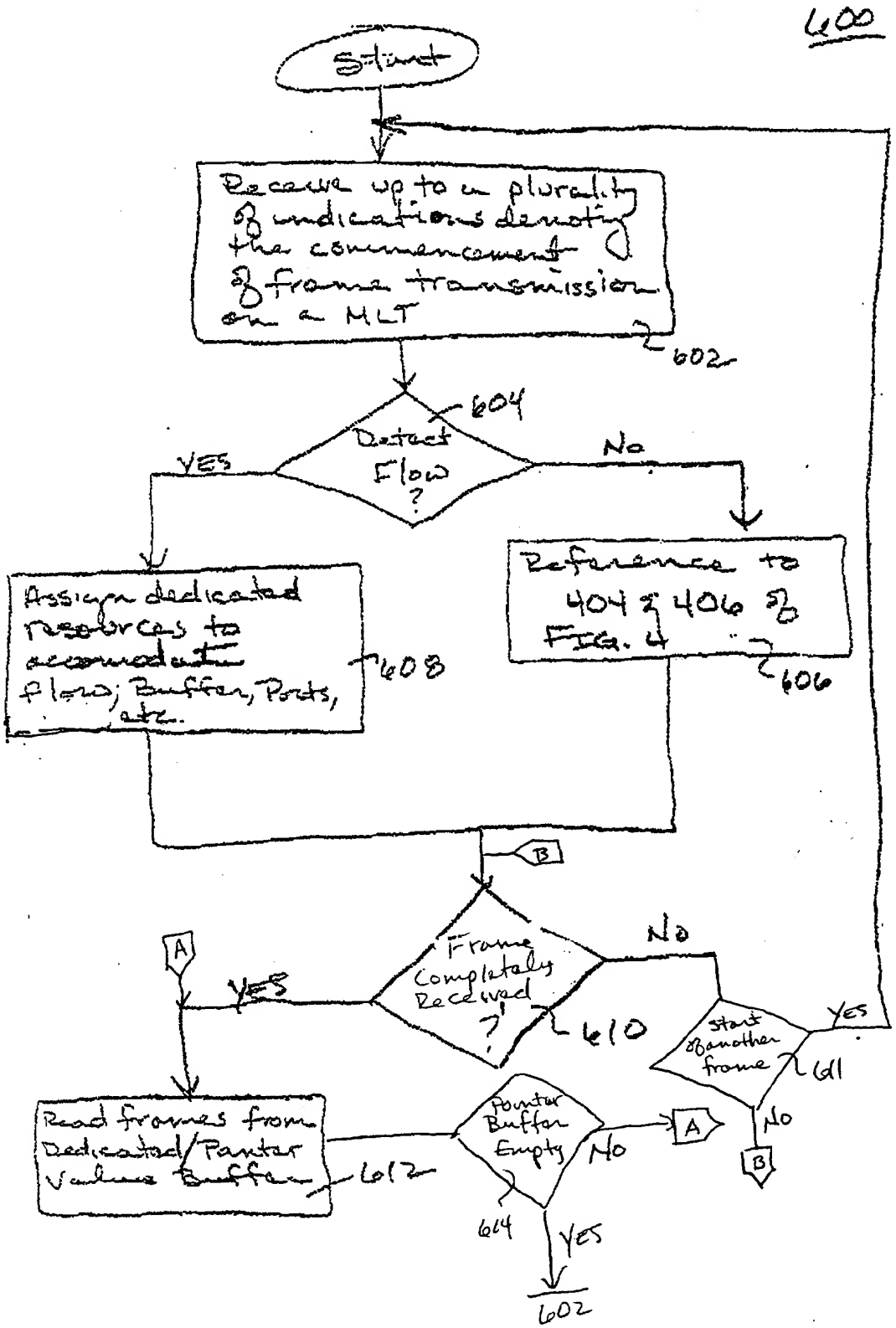
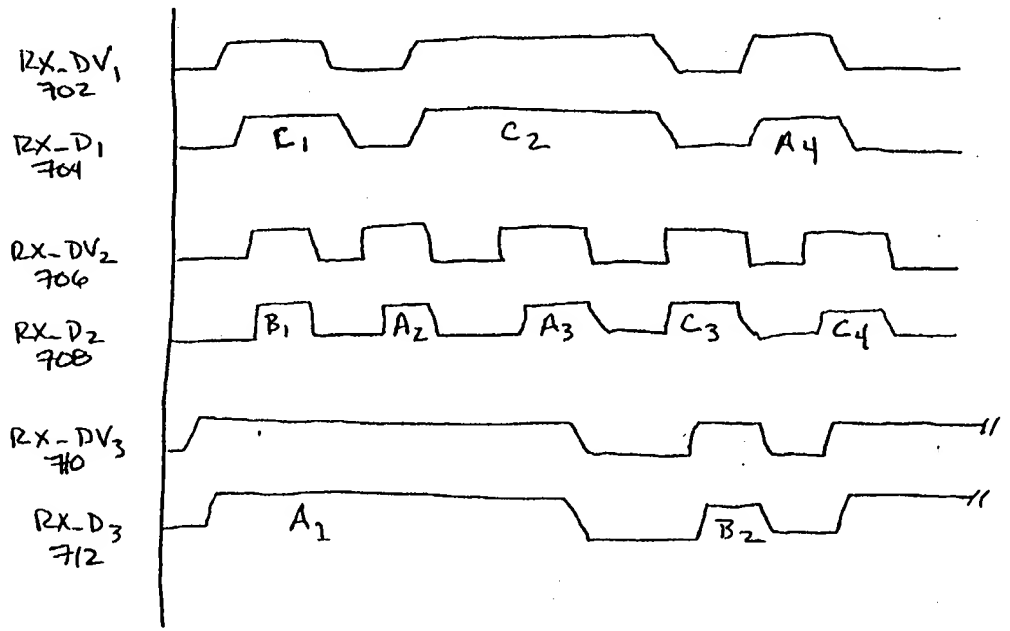

600
Start
Receive up to a plurality of indications denoting the commencement of frame transmission on a MLT
602
Detect Flow ?
604
YES
No
Assign dedicated resources to accomodate flow; Buffer, Ports, etc.
608
Reference to 404 & 406 of Fig. 4
606
B
A
YES
Frame Completely Received ?
610
No
Start another frame
611
YES
No
Read frames from Dedicated Pointer Values Buffer
612
Pointer Buffer Empty
614
No
YES
A
B
602

FIG. 7

700



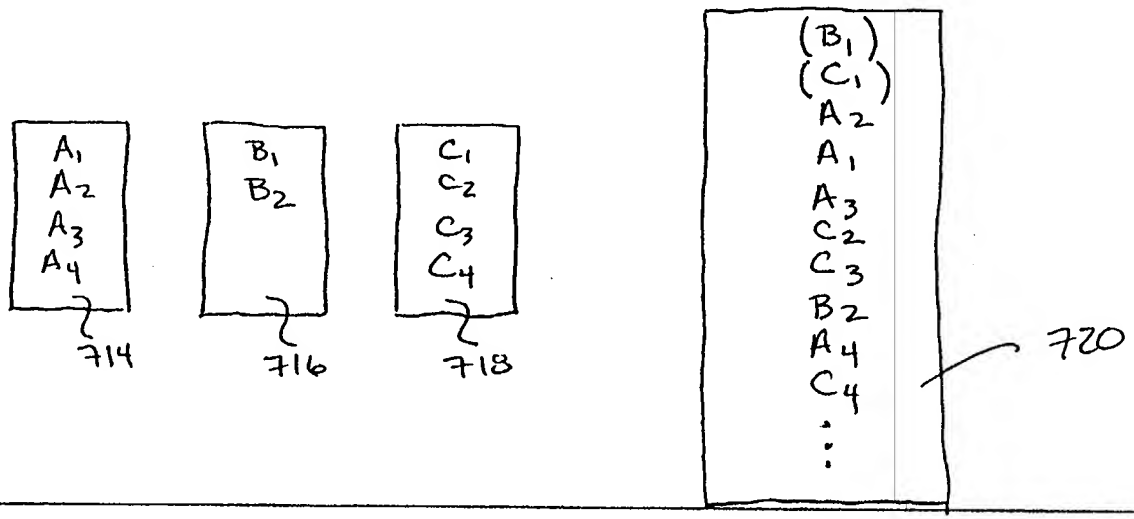
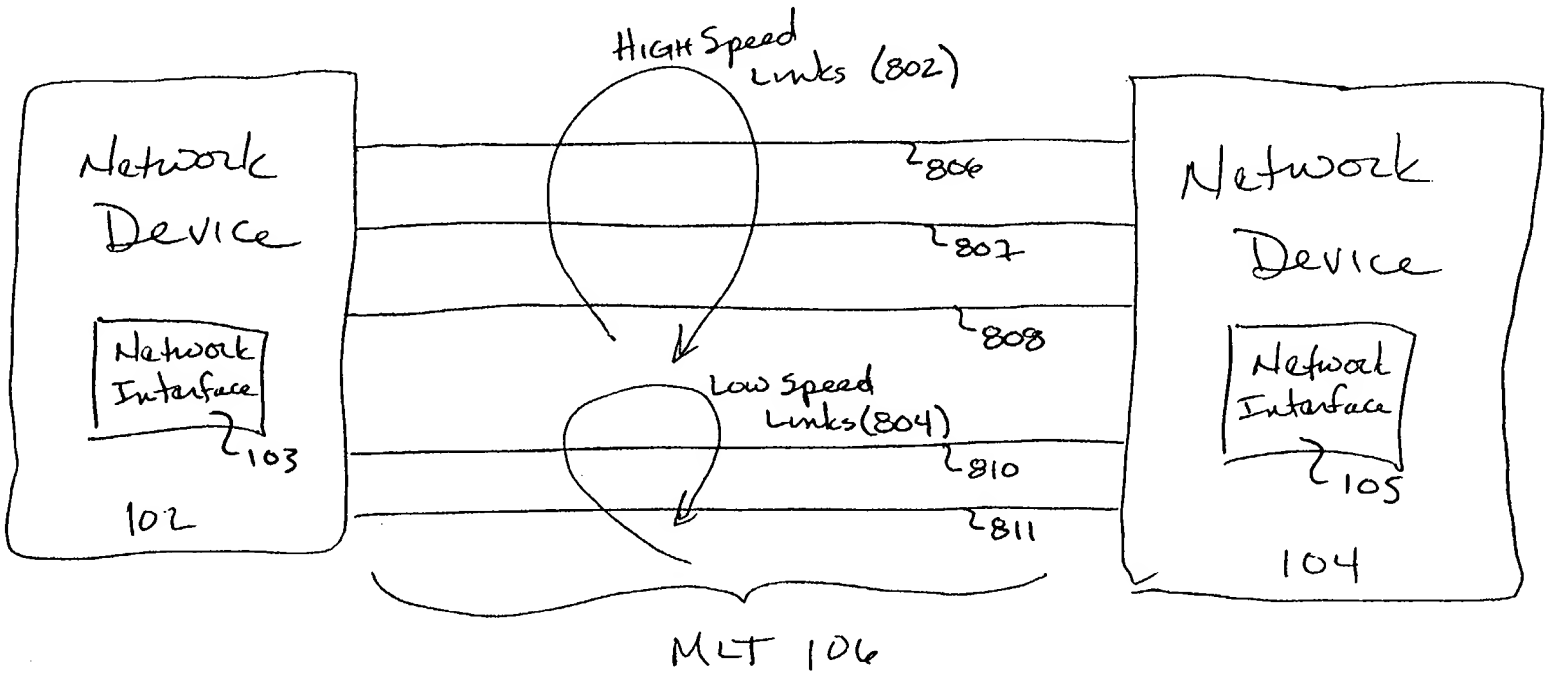


FIG. 8


High Speed Links (802)
Network Device
Network Interface
103
102
806
807
808
Low Speed Links (804)
810
811
Network Device
Network Interface
105
104
MLT 106

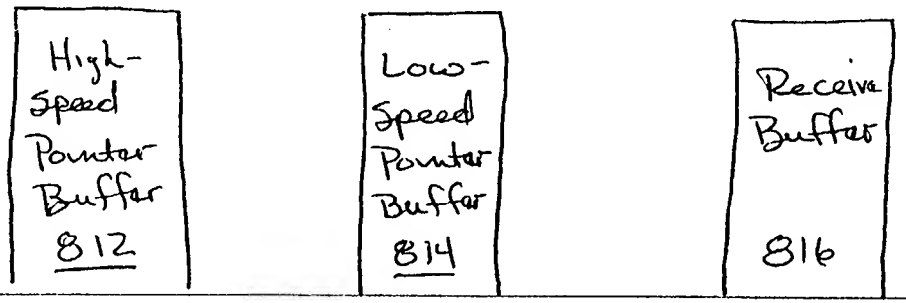

High-Speed Pointer Buffer
812
Low-Speed Pointer Buffer
814
Receive Buffer
816

FIG. 9

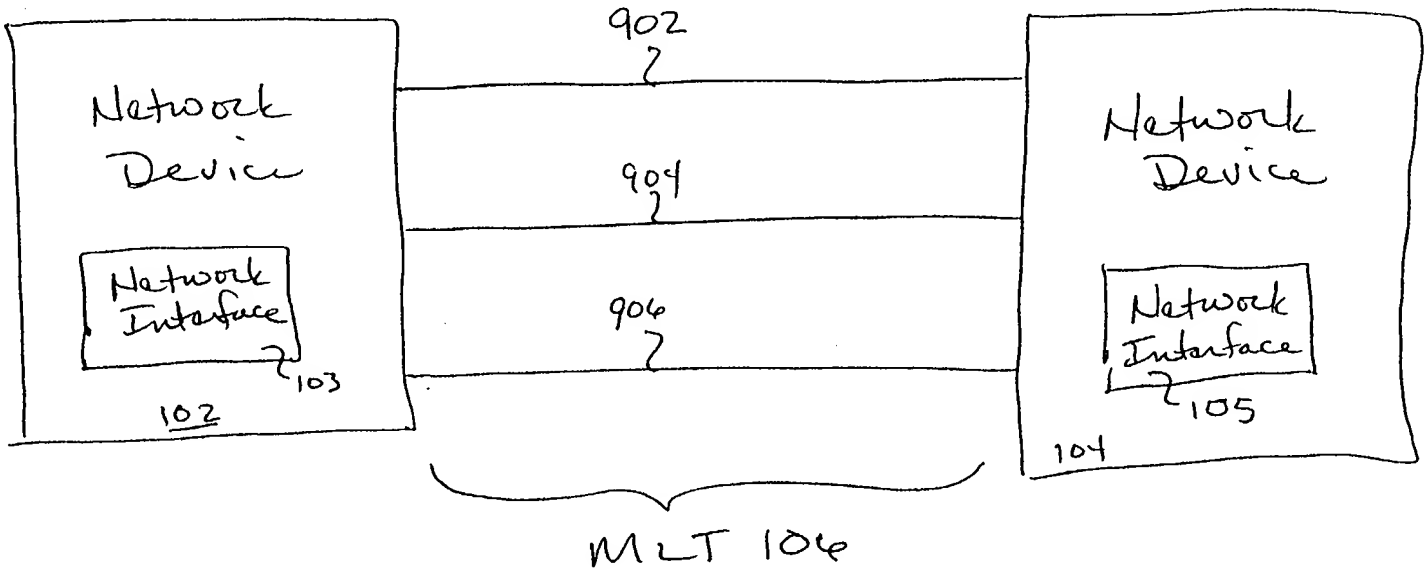
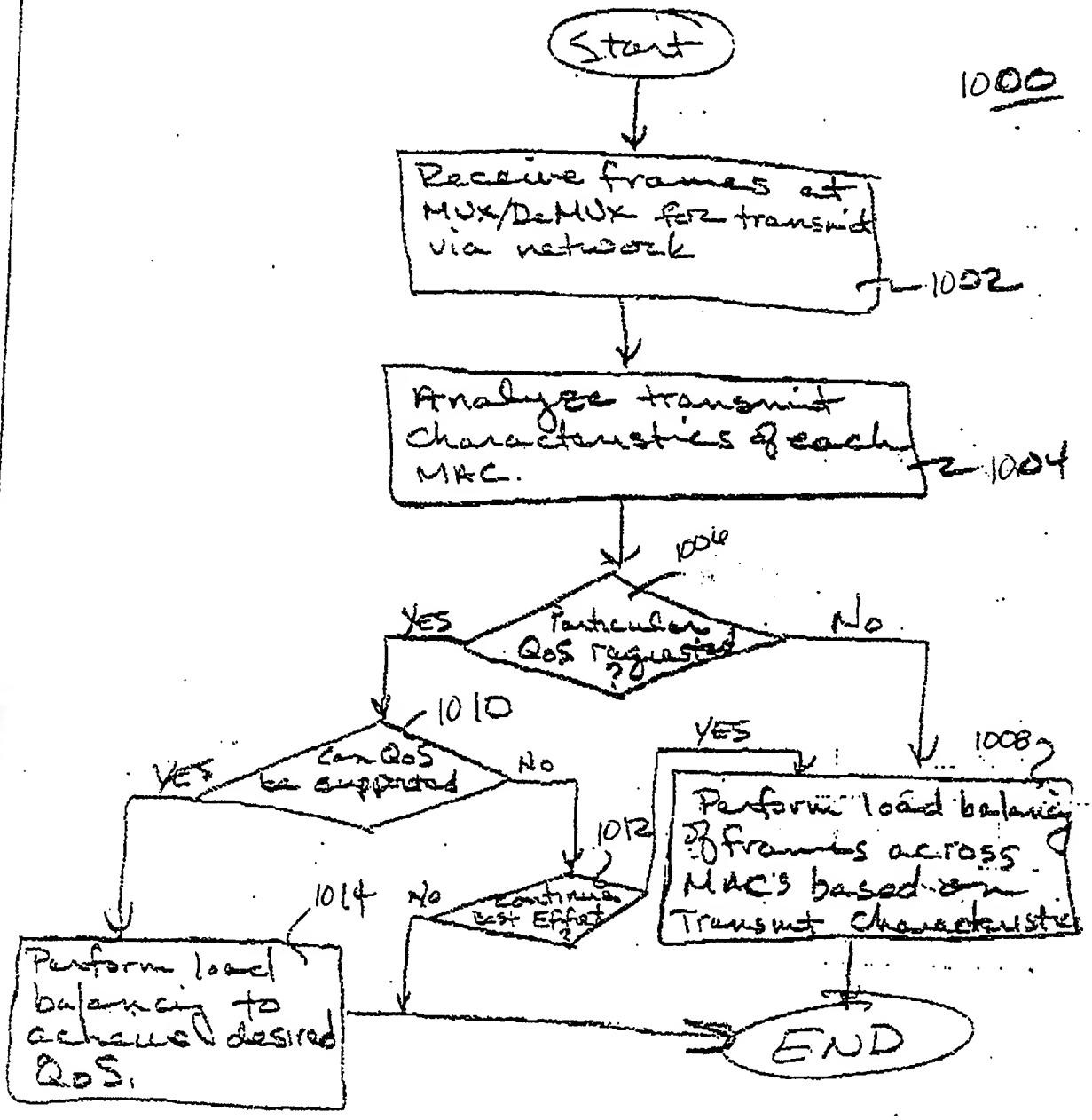


FIG. 10


Start
1000
Receive frames at MUX/DeMUX for transmit via network
1002
Analyze transmit characteristics of each MAC.
1004
1006
Particular QoS requested ?
YES
NO
1010
Can QoS be supported
YES
NO
1008
Perform load balancing of frames across MAC's based on Transmit characteristics
1012
Continue best Effort ?
NO
1014
Perform load balancing to achieve desired QoS.
END

Attorney's Docket No.: 82771.P270

Patent

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR PRESERVING FRAME ORDERING ACROSS AGGREGATED LINKS BETWEEN SOURCE AND DESTINATION NODES

the specification of which

[XXX] is attached hereto.
was filed on _____
as United States Application Number _____
or PCT International Application Number _____
and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	(Yes)	(No)
(Number)	(Country)	(Day/Month/Year Filed)	(Yes)	(No)
(Number)	(Country)	(Day/Month/Year Filed)	(Yes)	(No)

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

(Application Number) (Filing Date)

(Application Number) (Filing Date)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number) (Filing Date) (Status -- patented, pending, abandoned)

(Application Number) (Filing Date) (Status -- patented, pending, abandoned)

I hereby appoint Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Kent M. Chen, Reg. No. 39,630; Lawrence M. Cho, Reg. No. 39,942; Thomas M. Coester, Reg. No. 39,637; Roland B. Cortes, Reg. No. 39,152; Barbara Bokanov Courtney, Reg. No. P42,442; William Donald Davis, Reg. No. 38,428; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; Sharmini Nathan Green, Reg. No. 41,410; Richard Leon Gregory, Jr., P42,607; David R. Halvorson, Reg. No. 33,395; George W. Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; Stephen L. King, Reg. No. 19,180; Michael J. Mallie, Reg. No. 36,591; Paul A. Mendonsa, Reg. No. P42,879; Darren J. Milliken, P42,004; Thinh V. Nguyen, P42,034; Kimberley G. Nobles, Reg. No. 38,255; Michael A. Proksch, Reg. No. P43,021; Ronald W. Reagin, Reg. No. 20,340; Babak Redjaian, P42,096; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Anand Sethuraman, Reg. No. P43,351; Charles E. Shemwell, Reg. No. 40,171; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Allan T. Sponseller, Reg. No. 38,318; Geoffrey T. Staniford, P43,151; Judith A. Szepesi, Reg. No. 39,393; Edwin H. Taylor, Reg. No. 25,129; George G. C. Tseng, Reg. No. 41,355; Lester J. Vincent, Reg. No. 31,460; John Patrick Ward, Reg. No. 40,216; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my attorneys; and Thomas A. Hassing, Reg. No. 36,159 and Edwin A. Sloane, Reg. No. 34,728; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to: Allan T. Sponseller (Name of Attorney or Agent) BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN, L.L.P. 12400 Wilshire Boulevard, 7th Floor Los Angeles, California 90025

and direct telephone calls to: Allan T. Sponseller (Name of Attorney or Agent) 503)684-6200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Attorney's Docket No.: 82771.P270

Full Name of Sole/First Inventor (given name, family name) Mohan V. Kalkunte

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City , State) *(Country)*

P. O. Address _____

_____

Full Name of Second/Joint Inventor (given name, family name) James L. Mangin

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City , State) *(Country)*

P. O. Address _____

_____

Full Name of Third/Joint Inventor (given name, family name) Ian Crayford

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City , State) *(Country)*

P. O. Address _____

_____

Attorney's Docket No.: 82771.P270